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**The Mean Leeway Space in a Population
of Orthodontic Patients in Zurich**

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1 Summary

The space occupied by the primary canines and molars is greater than that required for the corresponding permanent teeth, the canine and the two premolars. This size difference of the primary and permanent teeth is known as the Leeway Space.

The Leeway Space becomes important during the change of dentition and the occlusal development. Precise knowledge of the available Leeway Space forms the basis for decisions about possible orthodontic treatment.

Previous measurements of the Leeway Space were only in partial agreement with each other. To throw further light on the situation, this investigation was aimed at clarifying the situation in Zurich.

One hundred suitable subjects were chosen and the teeth relevant for the Leeway Space measured on plaster casts from impressions taken both before and after the change of dentition. These subjects were chosen such that the sample contained equal numbers of males and females, both their dentitions were complete, there were neither fillings nor caries and no structural abnormalities of the dentin or enamel of the teeth.

In total 24 measurements were taken from study casts of each subject, i.e. the mesio-distal length of each tooth separately in the buccal segments of each quadrant, before and after the change of dentition. From these measurements the corresponding four values of the Leeway Space were derived.

The mean Leeway Space found in this study was 1.4 mm (± 0.84 mm) in girls in the upper jaw and 2.4 mm (± 0.78 mm) in the lower jaw. The values for boys were 0.94 mm (± 0.82 mm) in the upper jaw and 1.94 mm (± 0.85) in the lower jaw.

These values are approximate and serve as a guideline rather than a strict rule. They may help clinicians decide during the occlusal development of their patients whether therapeutic intervention becomes necessary or not. A common question/dilemma is whether there is enough space for all teeth or does one have to consider tooth extractions.

2 Introduction

The Space occupied by the primary canines and molars is greater than that required for the corresponding permanent teeth, the canine and the two premolars. This size difference of the primary and permanent teeth is known as the Leeway Space. On average 0.7 - 1.3 mm excess space exist in each upper quadrant and 1.6 - 2.7 mm in the lower quadrants with significant individual variation [1, 2, 3].

During normal occlusal development the change of the buccal segment starts approximately at the age of 9 $\frac{3}{4}$ in girls and 10 $\frac{1}{2}$ in boys and finishes 1 $\frac{1}{2}$ years later when the permanent canine of the maxilla erupts, varying individually.

The Leeway Space is available particularly because the second primary molars are on average 2 mm larger than the second permanent premolars [4]. Lower molars usually drift more mesially than the upper ones, which often strengthens Class I molar relationship, but also reduces space available for the front teeth. Space deficit, called physiological crowding, in the lower front area is typical once the permanent incisors have erupted. The Leeway Space can be utilized to solve this crowding simply by preventing the mesial drift of the lower 1st molars by a lingual arch placed before the exfoliation of the 2nd primary lower molars. A great part of the Leeway Space in the upper jaw is used up by the permanent canines which are usually 1mm wider than their predecessors [4].

In some cases the Leeway Space is reduced either when the deciduous teeth concerned develop cavities on approximal surfaces or have to be extracted too early due to decay [5]. In such cases an orthodontic treatment can become necessary to maintain the space for the permanent teeth [6]. Even in patients with minor crowding the space problem can be solved by preserving the Leeway Space [7, 8].

The measurements of the mean Leeway Space from previous investigations differ markedly:

Nance [1]:

lower jaw: 1.6 mm (boys), 1.8 mm (girls)

upper jaw: 0.7 mm (boys), 0.8 mm (girls)

Moorrees [2]:

lower jaw: 2.3 mm (boys), 2.6 mm (girls)

upper jaw: 1.3 mm (boys), 1.5 mm (girls)

Stöckli [3]:

lower jaw: 2.4 mm (boys), 2.7 mm (girls)

upper jaw: 0.8 mm (boys), 1.3 mm (girls)

3 Aim

As mentioned earlier, there are large variations in the Leeway Space.

Several previous investigations of the Leeway Space have been carried out and they do not fully agree with each other [1, 2, 3]. Therefore, the aim of this work is to evaluate the average Leeway Space found in girls and boys in the population of Zurich. We investigate the Leeway Space both in the upper and the lower jaw of patients who had orthodontic treatment during the three decades up to the year 2008.

Another reason for this work is to evaluate the most recent average Leeway Space in a population of orthodontic patients of Zurich. It is hoped that this will also help practicing clinicians to make decisions in planning orthodontic treatment during the occlusal development of their patients.

4 Methods and Subjects

This study uses plaster casts from patients who received orthodontic treatment at the University of Zurich in the department for orthodontics and paediatric dentistry between 1975 and 2008. A sample of 100 subjects, 50 girls and 50 boys, was selected. For the measurements two sets of plaster casts were used from each subject, one of the deciduous dentition, the other of the permanent dentition.

The mesio-distal crown size of the following groups of teeth at the points of mutual contact in each quadrant of each cast was measured:

- Group 1: deciduous canine, first and second molar
- Group 2: permanent canine, first and second premolar

In order to calculate the Leeway Space the sums of the sizes of the teeth in these two groups was formed. The Leeway Space is then the difference between the sums of the deciduous and the permanent teeth, which is group 1 minus group 2.

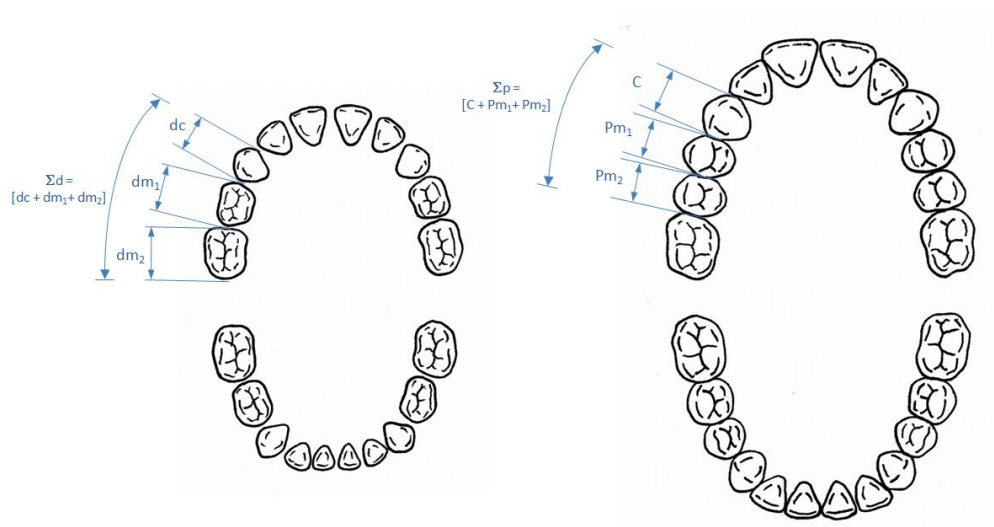


Figure 4-1 [9]: left: deciduous dentition, dc = canine, dm1,2 = first and second deciduous molars; right: permanent dentition, C = canine, Pm1, 2 = first and second premolars.

Before starting the actual measurements, digital and analogue callipers were compared by repeating several measurements with both types of callipers.

The actual measurements were then carried out using a digital sliding calliper. The branches of the calliper were sharpened to assure a precise positioning of the spikes (Figure 4-2).

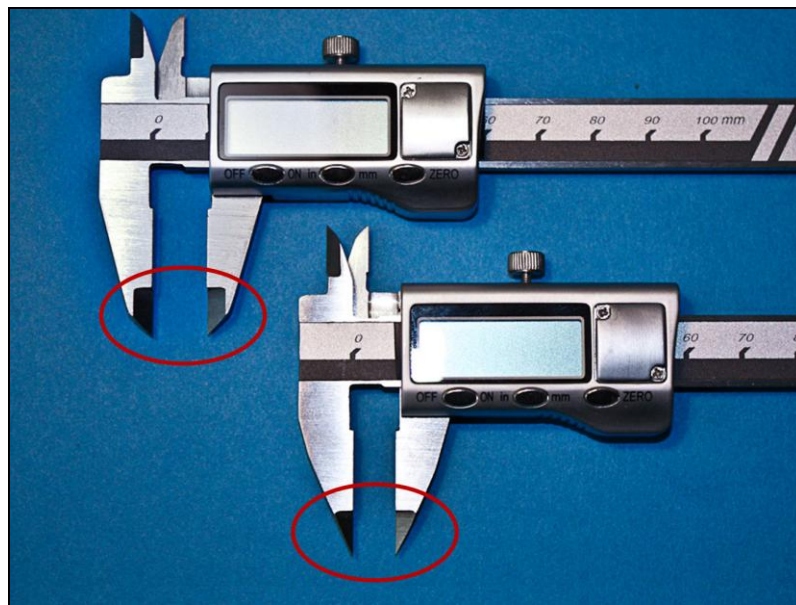


Figure 4-2 Original (upper) and sharpened (lower) branches of the digital callipers.

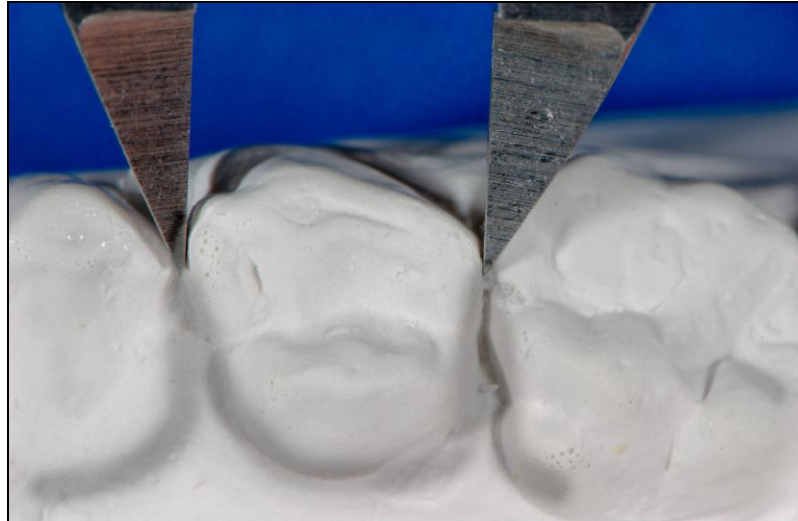


Figure 4-3 Precise positioning of the spikes at greatest width of each tooth.

Each tooth is measured separately at its greatest width. Figure 4-4 below shows an example of the measurements: on the left the deciduous first molar is being measured, on the right picture its successor of the same subject.



Figure 4-4 Example measurement of the deciduous first molar (left) and its successor, the first premolar, in the permanent dentition (right).

4.1 SUBJECTS

In order to facilitate the selection procedure of suitable subjects, the cases were chosen on the basis of initial intraoral photographs. This requires plaster casts of the

complete set of deciduous and permanent teeth of each individual. For the actual measurements a digital sliding calliper was used.

To ensure that each subject in the sample from which we shall compute the statistics contains all the parameters relevant to this study we selected a representative unbiased sample by ensuring that each individual had the same chance of being selected. In order to work with a population of suitable individuals only, we must impose a frame onto the selection process by admitting only those individuals who fit the inclusion criteria.

The inclusion criteria are:

- **Complete dentitions**
All the teeth need to be measured
- **No caries or fillings**
Can reduce or increase tooth size
- **High quality casts** of both the deciduous and permanent dentition precise contact points, no disturbing bubbles on casts
- **No pathologies** that affect the enamel or the dentin, i.e. all types of Amelogenesis imperfect and Dentinogenesis imperfect reduce tooth size
- **No cleft palate**
Variations in tooth sizes, even between left and right, teeth missing
- **No therapeutic slicing**
Tooth size is reduced
- **No extreme infraocclusion**
e.g. due to early ankylosis, because it is impossible to measure the greatest mesio-distal width of the tooth

Crowding or other abnormalities in tooth position are not relevant for this study and are not exclusion criteria as the Leeway Space is derived from the sum of the mesio-distal lengths of each tooth, measured separately, at their greatest width and not at the points of mutual contact.

4.2 STATISTICAL METHODS

The average Leeway Space and standard deviation together with the corresponding 95%-CI (Confidence Interval) for the true Leeway Space was assessed separately for boys and girls in each quadrant. Two way analysis of variance (ANOVA) was applied to the data.

To assure accuracy of the measurements, the following procedure was used:

Each individual measurement was repeated at least twice in order to eliminate measurement error. When the difference between measurements was less than 0.1 mm the measurement was accepted as reliable. If the difference was greater than 0.1 mm the measurement was repeated until a reliable result was obtained.

In order to assess the agreement between analogue and digital measurements the Bland-Altman method was used.

For the statistical computations PASW version 17 [10] and MedCalc version 10.1.8.0 [11] were used.

Results of the statistical analysis with p-value smaller than 0.05 were considered to be significant.

5 Results

The average Leeway Space found in girls is around 1.4 mm in the upper jaw and approximately 2.4 mm in the lower jaw. In boys the average Leeway Space is around 0.94 mm in the upper jaw and 1.94 mm in the lower jaw.

The standard deviation is around 0.8 mm in all cases. The computed mean Leeway Space together with standard deviations and corresponding 95%-CI for the true Leeway Space in each quadrant can be found in Table 1 for girls and in Table 2 for boys.

Girls	Mean Leeway Space	Standard Deviation	95%-CI	
	mm	mm	Lower bound	Upper bound
1.Quadrant	1.387	0.856	1.1432	1.6300
2.Quadrant	1.409	0.834	1.1719	1.6461
3.Quadrant	2.359	0.770	2.1399	2.5773
4.Quadrant	2.372	0.781	2.1500	2.5940

Table 1 Mean Leeway Space with Standard Deviation for girls

Boys	Mean Leeway Space	Standard Deviation	95%-CI	
	mm	mm	Lower bound	Upper bound
1.Quadrant	0.929	0.823	0.6953	1.1631
2.Quadrant	0.951	0.819	0.7185	1.1839
3.Quadrant	1.937	0.834	1.7003	2.1745
4.Quadrant	1.947	0.859	1.7030	2.1920

Table 2 Mean Leeway Space with Standard Deviation for boys

The distribution in Leeway Space in boys and girls in each quadrant is shown in Figure 5-1. The difference between upper and lower jaw as well as the difference between the sexes becomes apparent.

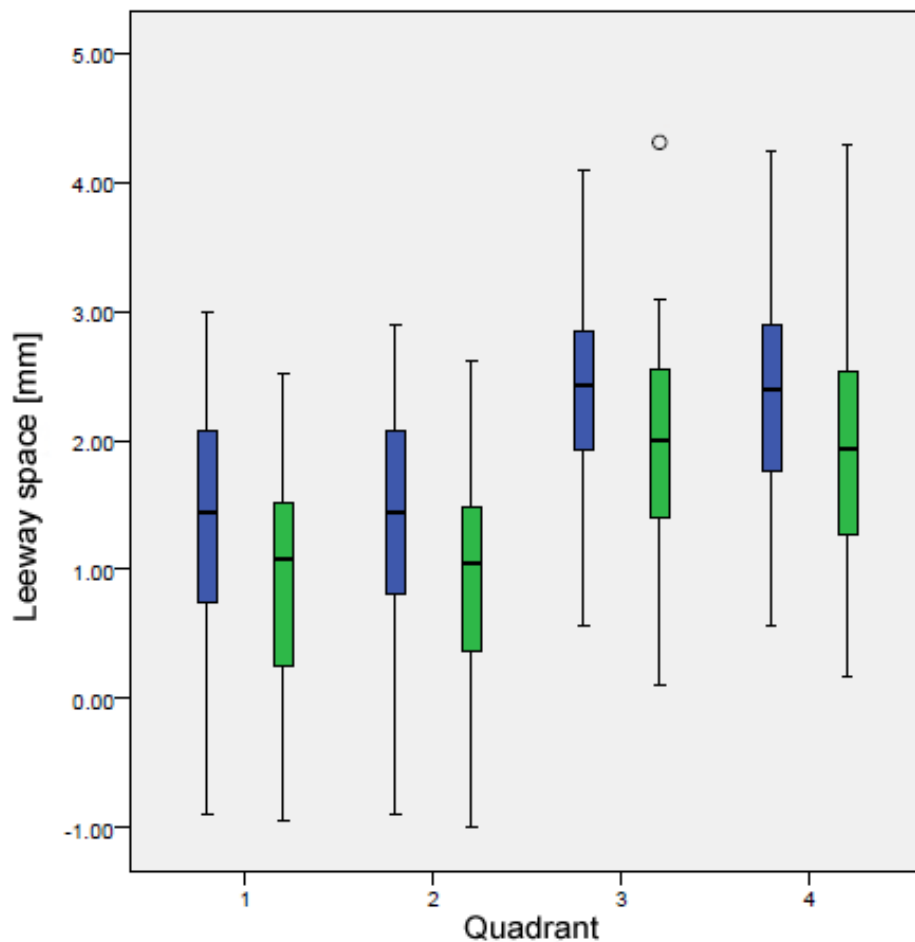


Figure 5-1 Distribution of the Leeway Space for girls (blue) and the boys (green) for each quadrant, the circle represents the only outlier.

Two way ANOVA revealed that girls have a larger Leeway Space than boys ($p < 0.001$) and the lower jaw has more Leeway Space than the upper jaw for both sexes ($p < 0.001$).

No significant difference was found between left and right side of each jaw.

The Bland-Altman method revealed that there is no indication that the digital method measures larger values of the Leeway Space than the analogue method. The Bland-Altman plots are given in the Appendix.

6 Discussion

There are essentially three possibilities to collect the data for the calculation of the average Leeway Space:

1. intra oral measurements of the teeth of test persons
2. extra oral measurements of the teeth on x-rays
3. extra oral measurements of the same teeth on plaster casts

The third possibility is to be preferred as it is very time consuming to find an appropriate set of test persons and the outcome depends on their compliance. Furthermore, the teeth of the same person must be measured before and after the change of dentition.

An additional problem is the confined intra oral space where the teeth must be measured as the subjects are children.

Measuring the teeth on x-rays has a further disadvantage, which is that the tooth size can be distorted depending on the angle of the x-ray film to the tooth and the direction of the ray during exposure. It is hardly possible to get the angle correct under normal clinical situations, especially as the patients are children.

Digital callipers which were used in the present study reduce the personal bias in reading the value and it is also possible to give the results with two decimal places rather than only one. Repeated measurements of the same teeth assure a higher reliability [12].

There is also the possibility of using three dimensional computer scans of the plaster casts for the measurements. This would require more effort and expense [13] as the models would have to be duplicated, sent to an institution specialised in producing the scans and measured with suitable software.

With very irregular positioning of the teeth the manual measurement becomes even more difficult as the contact points are not always the points of maximum width of the tooth. In such a case the computer assisted procedure would further increase the accuracy of the measurements.

However, studies do not fully agree with each other. Some state that the computer assisted measurements have higher accuracy and reproducibility [13], others conclude that measurements with callipers show higher reliability [14] or that the results of the computer assisted measurements over-estimated the actual dimensions [15]. Others again state that the results of the measurements performed manually hardly deviate from the results of the computer assisted measurements [16], so both methods can be considered equivalent.

The mean Leeway Space found in girls was 1.4 mm and 2.4 mm and in boys 0.94 mm and 1.94 mm in the upper and lower jaws, respectively. The values obtained in this study lie between the values from Nance and Moorrees [1, 2]. This holds particularly true in the lower dental arch where space issue is commonly more critical than in the upper dental arch.

In agreement with previous studies [1, 2, 3] it also became evident that girls in general have a larger Leeway Space than boys. This difference is also statistically significant. The fact that the Leeway Space is larger in girls than in boys is probably due to the fact that boys commonly have larger crown diameters than girls [4, 12]. Furthermore, in both sexes the Leeway Space in the lower jaw is statistically significantly larger than in the upper jaw. The difference between left and right is minor and not statistically significant.

In general small individual variations of the Leeway Space were found. Out of 100 subjects, i.e. 400 leeway values, only one subject was an outlier. The standard deviation was around 0.8 mm in all cases. Even though 0.8 mm variation is quite small, it may become clinically important if one has estimated the Leeway Space to be 2.5mm on both lower quadrants, and in reality total available extra space were 1.6 mm less. This overestimation might then lead to unacceptable space condition, and may necessitate space gaining, for example by stripping, if not extractions.

Compared with previous studies the results of this study are quite similar [1, 2, 3]. It should, however, be kept in mind that particularly concerning the lower jaw previous values from Zurich are larger than found in the present study. This difference may not be clinically important since in any case slight variations should not disturb the practicing clinician as the Leeway Space is always an estimate and serves more as a guideline rather than as a strict parameter.

7 References

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8 Appendix

The following figures show the detailed results of the Bland-Altman method comparing measurements with digital and analogue callipers. Both can be considered equal as the results do not differ significantly.

The following limits of agreement were found:

Q1: (-0.22, 0.26), Q2: (-0.42, 0.5), Q3: (-0.41, 0.37), Q4: (-0.28, 0.3).

